

# Geothermal Resources Available to California Markets

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# INTRODUCTION

- Summary of PIER-funded study
- Title: New Geothermal Site Identification and Qualification
- Part of : Hetch Hetchy / SFPUC Programmatic Renewable Energy Project
- Principal Authors: Chris Klein  
Jim Lovekin  
Subir Sanyal
- Project Coordination: Ray Dracker, CRS
- Project Manager: Valentino Tiangco, CEC

# CHRONOLOGY

- Contract with SFPUC – October 2002
- Report submitted to CEC – April 2004
- Companion study of existing facilities
  - Currently in progress
  - Scheduled for completion by mid-2005

# SCOPE OF WORK

- Two main components:
  - Geothermal reserves
  - Estimates of capital costs

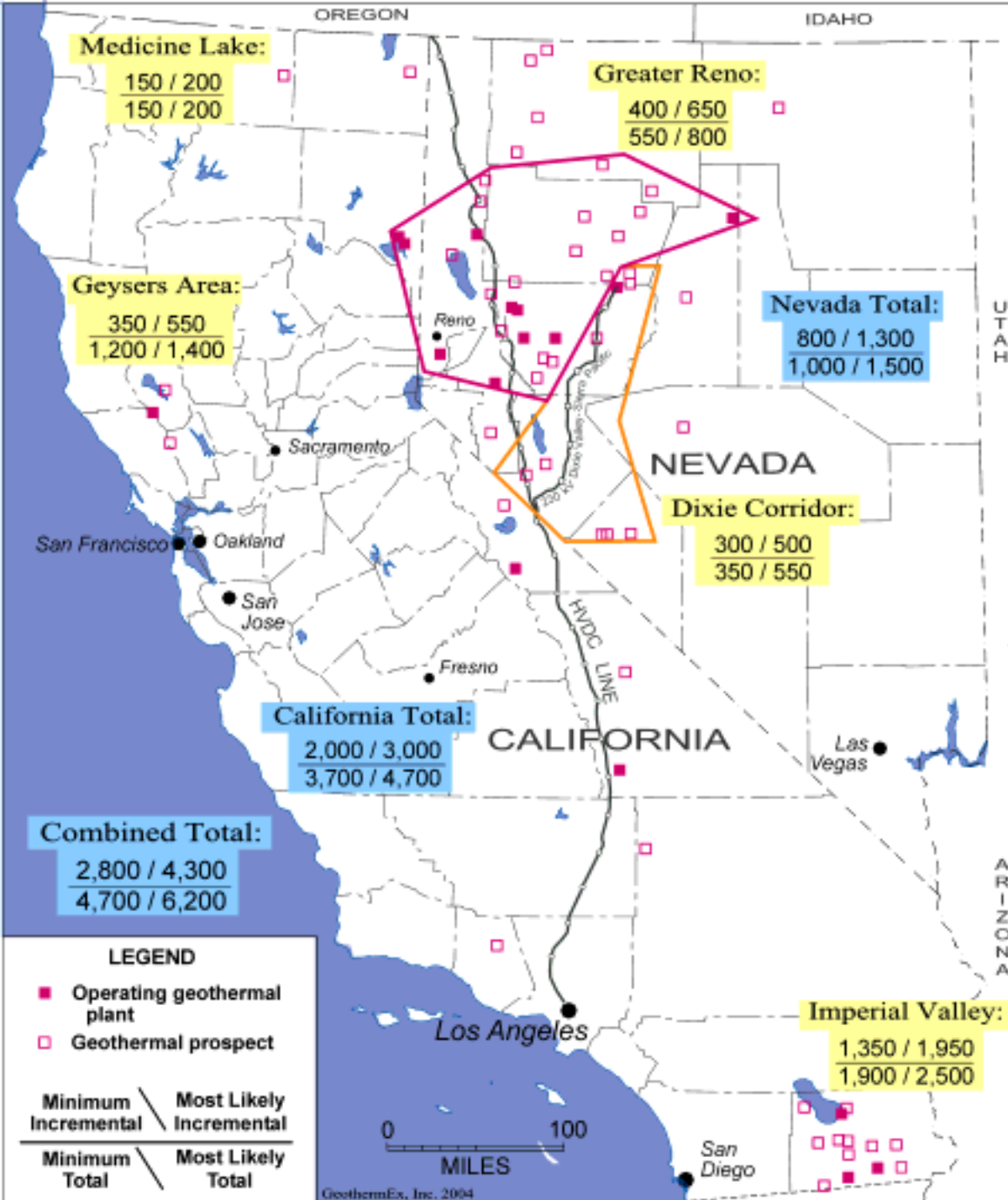
# PROJECT MATURITY

- Challenge has been to objectively assess and compare resources at different stages of development



# EXPLORATION – DEVELOPMENT CATEGORIES

- A. Existing power plant is operating
- B. No operating plant, but at least 1 well with tested capacity of 1 MW or more
- C. No well tested at 1 MW or more, but downhole temperature of at least 212°F
- D. Not meeting A, B, or C: resource properties from other sources (geology, geochemistry, geophysics)



# Generation Capacities of Major Geothermal Resource Areas in California and Nevada (Gross MW)

# CALCULATION OF RESERVES

## SUMMARY OF INPUT PARAMETERS

### Variable Parameters

	Minimum	Most Likely	Maximum
Reservoir Area (sq. mi.)	1.7	3.4	5.1
Reservoir Thickness (ft)	2500	3500	4500
Rock Porosity	0.03		0.07
Reservoir Temperature (*F)	340		380
Recovery Factor	0.05		0.20

### Fixed Parameters

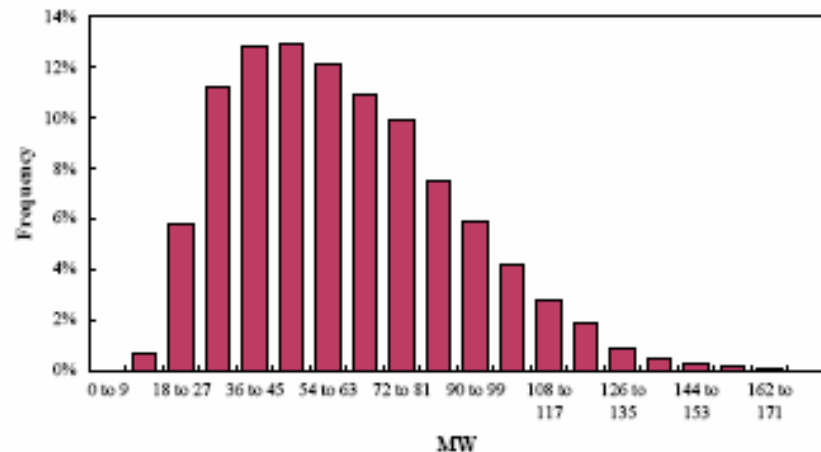
Rock Volumetric Heat Capacity	39.0	BTU/cu. ft*F
Rejection Temperature	50	*F
Utilization Factor	0.45	
Plant Capacity Factor	0.90	
Power Plant Life	30	years

## RESULTS

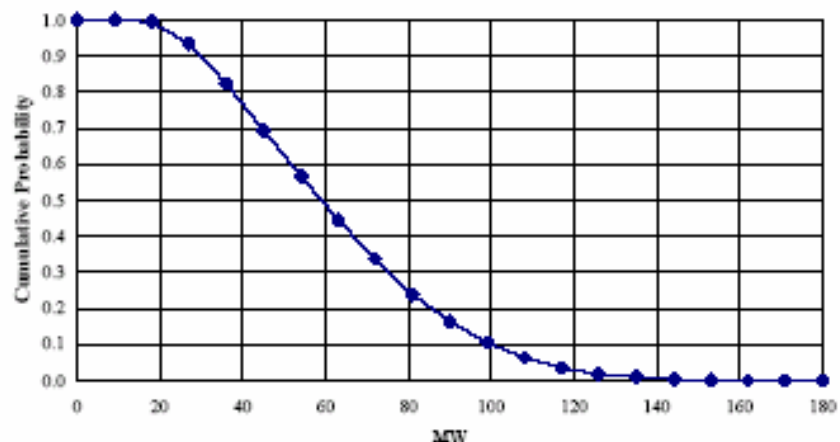
	Statistics		
	MW	MW/sq. mi.	Recovery Efficiency
Mean	62.40	18.39	1.23%
Std. Deviation	26.82	6.84	0.43%
Minimum (90% prob.)	30.14	9.43	0.64%
Most-likely (Modal)	46.95	12.90	0.83%

Figure FIS00-2:  
Probabilistic Calculation of Geothermal Energy Reserves  
FISH LAKE VALLEY, NEVADA

Histogram of Recoverable Geothermal Energy Reserves



Cumulative Probability of Recoverable Energy Reserves





# GENERATION CAPACITIES

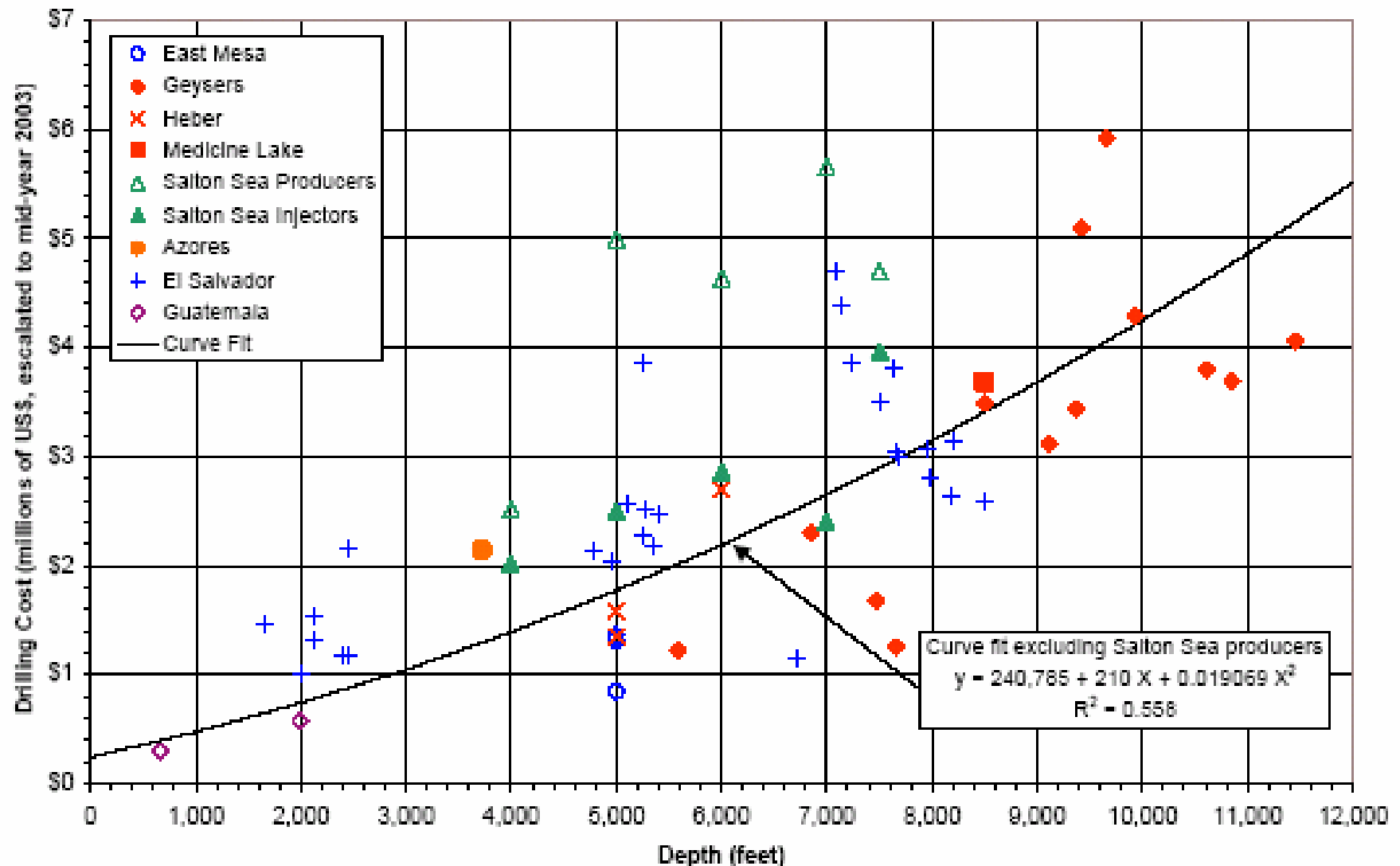
Area	Total Capacity		Capacity In Use (Gross MW)	Incremental Capacity		Most-likely Incremental As % of State Total	Most-likely Incremental As % of Grand Total
	Minimum (Gross MW)	Most-likely (Gross MW)		Minimum (Gross MW)	Most-likely (Gross MW)		
California							
Imperial Valley	1,900	2,500	550	1,350	1,950	65%	45%
The Geysers	1,200	1,400	850	350	550	18%	13%
Medicine Lake	150	200	0	150	200	7%	5%
Other	<u>450</u>	<u>600</u>	<u>300</u>	<u>150</u>	<u>300</u>	<u>10%</u>	<u>7%</u>
California Total	3,700	4,700	1,700	2,000	3,000	100%	70%
Nevada							
Greater Reno	550	800	150	400	650	50%	15%
Dixie Corridor	350	550	50	300	500	38%	12%
Other	<u>100</u>	<u>150</u>	<u>0</u>	<u>100</u>	<u>150</u>	<u>12%</u>	<u>3%</u>
Nevada Total	1,000	1,500	200	800	1,300	100%	30%
Grand Total	<u>4,700</u>	<u>6,200</u>	<u>1,900</u>	<u>2,800</u>	<u>4,300</u>	-	<u>100%</u>

Values rounded to increments of 50 MW

# COST COMPONENTS

- Exploration
  - Up to drilling first full-diameter well
- Confirmation
  - Drilling until 25% of specified capacity is available at the wellhead
- Development
  - Drilling until 105% of specified capacity is available at the wellhead
  - Surface equipment at \$1,500 / kW
  - Transmission-line interconnection

# DRILLING COSTS



# CAPITAL COSTS

- Overall Average (64 projects): \$3,100 / kW
  - Reflects all development costs (including transmission)
  - \$2,950 / kW within California
  - \$3,400 / kW in Greater Reno and Dixie Corridor
- Incremental geothermal capacity available:
  - 2,500 MW (gross) below average cost of \$3,100 / kW
  - 2,000 MW (gross) within California below state average of \$2,950 / kW
  - 1,700 MW (gross) below \$2,400 / kW (assumed threshold to be competitive with other renewables)
- Subject to further updating once operators and developers have opportunity to comment on report

# PIER GEOTHERMAL DATABASE

**Choose Project**

**Hetch Hetchy/SFPUC Programmatic Renewable Energy Project  
Project 1.3: Geothermal Project Areas**

PROJ ID	CO800	<input type="button" value="Add New"/>	Owner	Caithness Energy LLC	<b>Notes: Project</b> Nine turbine-generator units at four plant sites in three project areas: Navy I (CO801), Navy II (CO802) and BLM (CO803). Power is sold to Southern California Edison. All project areas are within the China Lake Naval Air Weapons Station. MW installed values are listed separately for each project. Fieldwide total is 300 MW-gross and 270 MW-net. The MW produced in 2002 is based on data in Figure CO800-3.
Area	4	<input type="button" value="Set as New"/>	Developer	California Energy Company, Inc.	
Name: District/Area/Field	Coso		Financier		
Name: Area/Power Plant	Field-wide Summary		Operator	Coso Operating Company LLC	
KGRA	Coso Hot Springs		MW Installed	300 -gr 270 -net	
State	CA	County	MW produced (yr)	275 (2002)	
Lat(N)	36.03°	Long(W)	Plant Technology	Dual Flash	
			Start Date Yr	1987(Navy I)	
			Exploration-Development Category	A	
			Generation Capacity Estimated?	Y	

**CURRENT PROJECT DATA SCREENS**

Contacts	Reservoir Physical Properties	Generation Capacity
Land	Reservoir Chemical	Exploration Program
Explor-Dev History	References	Confirmation Costs -
Government	Figures	Confirmation Costs -
Well Summaries		Development Costs -
Operational		Development Costs -

**CURRENT PROJECT DATA REPORTS**

Data Summary	Expl - Conf - Dev Programs & Costs	Figure	References
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**OTHER SCREENS & REPORTS**

Location map (Fig.1)	?
Project References by Author	
All Other References (Gen. Citations)	
Abbreviations & Definitions	
Multi-Project Reports & Documents	
Query Main Facts	?
Description of Database	
How to use the database	
<input type="button" value="Close"/>	

# How to Get a Copy

- Full report and PIER Geothermal Database are available for free download at:
  - [www.geothermex.com](http://www.geothermex.com)
  - On the Home Page, click on CEC-PIER Reports
  - Report is 264 pages (4.2 MB)
  - PIER Geothermal Database is 45.1 MB (zipped)

# SUMMARY

- Reserves (Gross MW)
  - Incremental: 4,300 MW
  - Incremental Within California: 3,000 MW
- Costs
  - Average overall: \$3,100 / kW
  - Includes estimate of transmission tie-in
- Power Available (Gross MW)
  - Below \$2,400 / kW threshold: 1,700 MW

# Back-up slides

- The following may be used if time permits or if needed to respond to questions



# Exploration – Confirmation Costs

- Geology (field mapping)
- Geochemistry
- Geophysics
  - Gravity
  - Magnetics
  - Resistivity (e.g., TDEM, AMT, CSAMT)
- Intermediate-depth slim holes
- Full-sized confirmation wells (including testing)
  - Success rate 60% for confirmation wells
- Regulatory compliance
- Administration
- Resource assessment report

# Development Costs

- Production and injection wells
  - Ratio of injectors to producers depends on technology used (e.g., flash or binary)
  - Success rate 80% for development wells
  - MW per well based on statistical correlation of MW vs. reservoir temperature
- Surface facilities on site: \$1,500 / kW
  - Applied for all plant technologies (flash or binary)
- Transmission tie-in estimated in conjunction with separate analysis by another contractor for Hetch Hetchy / SFPUC Project

# Exploration-Development History

- Geology, geochemistry, geophysics
- Past drilling
  - Temperature-gradient holes
  - Intermediate-depth slim holes
  - Self-flowing production wells
  - Pumped production wells
  - Injection wells
  - Observation wells
  - Includes completion statistics if available

# VOLUMETRIC CAPACITY ESTIMATE

- Reservoir properties
  - Average temperature
  - Depth to top
  - Thickness
  - Area
  - Porosity
- Other factors
  - Recovery factor (0.05 to 0.20)
  - Heat capacity of rock (39 BTU/ft<sup>3</sup> °F)
  - Utilization factor (45%)
  - Capacity factor (90%)
  - Plant life (30 years)